APPENDIX F.

Geology and Soils

Appendix F – Geology and Soils

Route description by Fugro (2004)

The objective of the MARS survey was to enable the selection of a safe and economic submarine cable route, to assess cable protection requirements, and to provide information for the engineering, laying and subsequent maintenance of the cable. With this aim, the geophysical survey provided seabed and shallow subsurface geological information continuously along the MARS route – the bathymetry being provided by MBARI. This data was later complemented by a Mini Cone Testing (MCT) program designed to help assess soil conditions at 31 different locations along the MARS route (as detailed before in Section 4).

It should be noted that, at MBARI's request, additional geotechnical data collected in 1999 during a survey for the Southern Cross Fiber Optic Cable route have been used for this study. These data, which consist of a total of 37 Cone Penetrometer Tests (MCI-CPT035 through MCI-CPT 071) and four (4) Push Samples (PS-005 through PS008), were provided by MBARI prior to this report and integrated onto the MARS survey charts. In order to clearly differentiate this dataset from the data specifically acquired for the MARS project, the location of all Cone Penetrometer Tests (CPT) and Push Samples (PS) are shown in red on the survey charts. The MCTs collected during the MARS survey are displayed in black.

The results of the geophysical survey performed along the MARS cable route combined with the MCT, CPT and PS results are described in detail in this section and on a series of 13 alignment sheets that accompany this report (see Volume II). All descriptions, presented here, are made from offshore Moss Landing towards the MARS observatory node located at a water depth of 891 meters; i.e. from Chart as001 through Chart as013 in an east-to-west direction across the continental shelf and north-to-south along Smooth Ridge.

SEABED MORPHOLOGY AND GEOLOGY ALONG THE ROUTE

<u>Along the continental shelf</u>

The initial portion of the MARS route offshore Moss Landing runs from a water depth of 17.5 meters, near the end of the Duke Power Plant pipeline, to the north of the shallow multiple heads of Monterey Canyon (Chart as001). From this location, between approximately 121°48.00'W and 122°06.00'W, or from 20 to 90 meters water depth (KP0 to KP30 on Charts as001 through as007), the MARS route runs across the continental shelf over a relatively featureless and gently sloping seabed that consists primarily of unconsolidated sand, silt and clay (or a mixture of these) with local areas of dense/coarse sand and hard/firm clay. It should be noted that many water column anomalies, visible on the side-scan sonar data, occurred in this area that appear to result from fish, squid or bait balls.

On Chart as001, water depths along the shelf increase gently towards the west from 17.5 to 25 meters and slope gradients are less than 5° within the entire survey corridor. In the vicinity of the Duke pipeline, at the start of the route, several patches of sand ripples and dense sand are observed over a local shoal in water depths of less than 20 meters. Along this portion of the route, the subbottom profiler only achieved limited penetration through the substratum and no reflectors were observed. However, our data combined with the results of the MCT information suggest that the surficial sediment cover of loose to medium dense sand (with clay laminations) is generally 1.7 meters thick or greater.

Please note that the presence of the Duke Energy pipeline in the vicinity of the sand ripple areas is discussed later in Section 5.2.

On Chart as002, east of 121°51.00'W, the route runs towards the northwest more or less parallel to the bathymetric contours. In this area, the seabed is relatively featureless with an average water depth of 25 meters and consists predominantly of weakly layered loose to medium dense sand, or clayey sand, greater than 2 meters in thickness. West of 121°51.00'W, the seabed deepens gently to 35 meters and the subbottom profiler data show a greater penetration into the sediment. We interpret the change in acoustic facies to a possible transition in the soil composition from sandy to predominantly clayey sediments, as confirmed by the MCT results obtained further to the west.

On Chart as003 and most of Chart as004, between approximately 121°52.00'W and 121°56.60'W, the route undulates gently towards the west-northwest with water depths ranging from 35 to 45 meters. The seabed comprises predominantly thick (greater than 2 meters) very soft-to-soft clay, or sandy clay, with sand laminations increasing at a depth of 1 meter below the seabed. The sediments are generally well layered throughout this portion of the route and no major obstruction is expected.

From approximately 121°56.60'W to 122°00.60'W (or between KP15.25 and KP21.3), the bathymetric data show that the seabed undulates very gently between 38 and 49 meters water depth over a series of small ridges and depressions that extend more or less in a north-south direction (Charts as004 through as006). Seabed gradients are typically less than 5° in this area and a mixture of clayey sand and sandy clay dominates at the seafloor. The limits between the two major sediment types (i.e. sand and clay) are generally diffused and were identified from changes in the sediment reflectivity on the side-scan sonar records. MCTs and subbottom profiler data collected in this area show that the sediment cover is typically weakly-layered and greater than 2 meters in thickness.

Around 122°00.60'W (~ KP21.3), at a water depth of 49 meters, the seabed starts deepening more steadily towards the west and consists primarily of very soft to firm sandy clay and silt, although occasional patches of sand may occur (see Chart as006). From this location to a water depth of approximately 90 meters, around 122°06.00'W (~KP30), the route runs over a series of small steps, 3 to 5 meters in height, over which harder clays or possibly dense sand patches are encountered. Although no internal reflections are observed on the subbottom profiler data, the surficial sediment cover of sandy clay and silt is expected to form a layer greater than 2 meters thick in this area (Charts as006 and as007).

<u>At the shelf edge and along the continental slope</u>

The 90-meter water depth contour, around 122°06.00'W (~ KP30), marks approximately the edge of the continental shelf and corresponds with a clear thinning of the surficial sediment cover, as shown in the western part of Chart as007. We also interpret this contour as being approximately the limit between Quaternary muddy deposits (to the east) and sediments of the Purisima Formation, which are characterized by siltstone and sandstone of Pliocene age (to the west).

In the upper part of the continental slope, between 90 and 105 meters, the seabed comprises primarily very dense clayey sand with a discontinuous cover of very soft clay or silt typically less than 0.7 meters thick, as revealed by the geotechnical data (see Chart as008). The limited extent of penetration at most of the MCT and CPT locations suggests that, in this area, the sands can be locally very consolidated (possibly siltstone/sandstone) at a depth as shallow as 0.14 meters below the seabed.

In the western part of Chart as008, around 122°07.75'W (e.g. ~KP33), the 105-meter water depth contour corresponds with a marked change in the seabed geology, and with a more significant drop of the seafloor towards the southwest as the route runs down the neck of Smooth Ridge. Below this water depth, our side-scan sonar records show the presence of numerous rock outcrops or rubbles along the slope (Chart as008 through Chart as010). In addition, most of the CPT, MCT and PS data collected in this region reveal a **refusal at shallow depth** below the seabed and the presence of **very stiff to hard cemented** clay, which can be as challenging as rock as far as plowing operations are concerned (see discussion in Section 5.3). For these reasons, although the geotechnical data suggest the presence of clay as a major soil component along the neck of Smooth Ridge, we displayed this entire area as "rock" on the survey charts. Subbottom profiler data collected between 105 and 140 meters water depth show several strong reflectors dipping seaward, with a stratal dip slightly greater than the slope of the seafloor. This observation is in general agreement with the results of previous studies discussed in Section 2.1, which suggest that hard or cemented layers likely crop out at the shallow end of Smooth Ridge.

In the central part of Chart as009, the MARS route runs steeply along the walls of a canyon located exactly in the axis of the Carmel Canyon, which can be identified further to the southeast (see also Section 2.1). The canyon exhibits a V-shape, with its axis centered around 122°10.00'W (~ KP37). Along the canyon wall, seabed gradients are up to 18° within the survey corridor and 14° along the route, and the seafloor is primarily composed of hard carbonate cemented rubble and, most likely, rock outcrops.

The area between 160 and 320 meters water depth, on the eastern flank of the canyon, is particularly steep and disturbed. Subbottom profiler data collected in this region allowed us to identify – on all survey lines – a weak but consistent reflector dipping seaward, which is interpreted as the location of the San Gregorio Fault. In general, the reflector does not reach the seabed surface. However, when prolonged towards the surface it shows that the fault would cross the seabed around the 227-meter water depth contour (along the route) and would extend in a N-S to NNW-SSE direction, as shown on Chart as009. The disturbed area that marks the passage of the fault (between the 208-meter and the 311-meter contours along the route) is interpreted as the fault deformation zone. Our observation is more or less in agreement with previous studies of the San Gregorio – Palo Colorado Fault, which suggest that the fault occurs in slightly greater water depth between 250 to 350 meters, as opposed to 227 meters (see discussion in Section 2.1).

The studies mentioned above also suggest that many kilometers of lateral offset occur across the San Gregorio Fault and that therefore the substrates on both sides are unrelated. On the east side of the fault, the seabed should consist predominantly of sandstone and siltstone of the Purisima Formation, while on the west side of the fault it should be mostly composed of mudstone of Pliocene age. Our geotechnical data do not allow, however, differentiating between the two formations and reveals in general the presence of very stiff to cemented clay in the area along the neck of Smooth Ridge. Additional seabed samples would be necessary to ground truth our geological interpretation, but unfortunately, no sampling was performed during the MARS survey. It should be remembered that in the area of the narrow neck of Smooth Ridge, hard grounds and carbonate concretions may be locally associated with the passage of the San Gregorio Fault, which provide a conduit for mineralized fluid seeps.

West of the canyon feature mentioned above, i.e. west of 122°10.00'W (~KP37), the route turns towards the south-southwest. The seabed is more regular and deepens gently from 308 to 420 meters water depth along the neck of Smooth Ridge, with slope gradients of less than 6° (Charts as009 and as010). In this area, the rise extends in a NNE-SSW direction and is flanked on both sides by numerous steep scarps that are well imaged in the side-scan sonar records, in particular south of 36°49.00'N. Our data suggest that these scarps are associated with areas of mass failure and well-developed slumps. Along the neck of the ridge, the slope is covered with very stiff to hard, cemented clay and hard carbonate rubble, and only weak reflectors can be observed on the subbottom profiler data.

As the water depth increases along Smooth Ridge, between 420 and 450 meters, a thin cover of sediment progressively overlies the rubbles and the substratum becomes less stiff and weakly cemented. Strong reflectors, dipping to the south, start to appear in the subbottom profiler records as greater penetration is achieved in these softer sediments (Chart as010).

At approximately 450 meters water depth (~KP41.25), a clear limit is observed on the side-scan sonar records between the very reflective rubble area that cover the neck of Smooth Ridge (to the north) and the less reflective softer sediments further down the slope (Chart as010). South of this limit, the seabed is predominantly covered with well-layered soft to firm sandy clays, which thicken towards the south. As shown on Charts as010 through as013, the seafloor is relatively featureless and deepens gently in this area, with gradients of less than 8°, down towards the location of the observatory node. Along this section of the route, the only remarkable feature is a small 10-meter high ridge located around 36°44.80'N (~KP47.15), which culminates at a water depth of 762 meters.

At the end of the MARS cable route, the observatory node is located at a water depth of 891 meters (KP51.020) on the southeastern flank of Smooth Ridge. In this area, the seabed is smooth, featureless and blanketed with a thick (5 to 10 meters) unconsolidated well-layered sediment cover of clay. No hard substrate and no indication of seafloor instability were observed in this region (Chart as013).

OBSTRUCTIONS

Although the MARS cable route was designed to avoid all restricted areas and obstructions, where possible, a number of these still exist across, or in the vicinity of the route. Their positions are given in Section 2.3 and plotted on the survey charts presented in Volume II.

Because it directly impacts upon the cable installation and was chosen as the starting point for the MARS cable route, we provide in this section some details regarding the presence of the Duke Power Plant oil line (pipeline), which lies in the shallow waters off Moss Landing.

The pipeline, owned by Duke Energy, extends in a west-northwest direction from the shore to a water depth of approximately 18 meters (MBARI bathymetric data), as shown on Chart as001. Because it is considered as a possible landing for the MARS cable, MBARI required that the exact position of the end of this structure be identified during the MARS survey.

The original position for the offshore end of this pipe was taken off the nautical chart 18685 at: 36°48.719'N – 121°48.037'W (in gray on Chart as001) and set up as the main target for the survey. The pipeline was indeed identified during the survey only 10 to 20 meters away from this target position, as a clear linear trend on side-scan sonar records, with its end at: 36°48.738'N – 121°48.071'W. It is plotted in black on Chart as001.

An image of the pipeline at this location, displayed on Figure 5.2.1 below, shows that the location of the Duke Energy pipe corresponds with a linear (perpendicular to shore) accumulation of coarse-grained material.

Several additional sonar targets that appear to be man-made were also imaged in the vicinity of the pipeline. These may represent anchor blocks for the old mooring buoys used by oil tankers offloading at the pipeline, or other debris of unknown nature. In total, seven (7) sonar targets have been identified from our side-scan records. They are all plotted on Chart as001 and described in Table 5.2.1 below, as they might constitute a hazard to the MARS cable.